A Review of the Yagi-Uda Aerial

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THE Yagi-Uda aerial was developed over 35 years ago in Japan by H. Yagi and S. Uda, and has since become a well-known array, not only in the Amateur Radio field. In its usual form, the aerial is constructed from a number of simple dipole elements in such a manner that the direction of maximum radiation lies in the plane of the elements and along the normal to the elements. The elements are parallel and separated by some fraction of a wavelength. The simplest type has a single reflector or director in conjunction with the driven element, although models have been constructed with 42 or more parasitic elements. In the majority of cases the array will have only one driven element; however, two driven elements have been used in order to produce a wider than normal operating bandwidth. The other elements are parasitic because they " feed on," or accept, the radiation from the driven element and one another and re-radiate it.

One may see that the term " end-fire array " is aptly applied to the Yagi-Uda (as it is to certain other aerials), but perhaps not so obviously, the expression " travelling surface-wave aerial " or array. By looking at it from this second point of view it has been found possible to obtain a design method applicable to the longer Yagi-Uda aerials which is somewhat easier to handle than the conventional empirical methods. The latter methods, though, have been developed to such a degree that quite good designs over a wide range of frequencies can be obtained using the graphs and tables to be found in various papers and handbooks.

The early Yagi-Uda aerials were used in the upper h.f. and lower v.h.f. ranges. They comprised relatively few elements, which could be looked upon as discrete but mutually coupled circuits. At this stage it was fairly easy to construct an array optimized with respect to a certain characteristic, e.g., sidelobe level, forward gain, etc. It was even possible to analyse the array mathematically, though for more than three or four elements the equations became too complex to handle. These could doubtless be solved now by a digital computer, but it is probably simpler and cheaper to use design charts.

Later, the u.h.f. band and higher frequencies became widely used and naturally the physical dimensions permitted the use of long arrays with many elements, together with large reflecting surfaces. The result was that various designers obtained similar performances from aerials of a dissimilar design, the result being a certain amount of confusion as to the optimum design.

The subject matter concerning the Yagi-Uda is sufficient to fill a book and it is impossible to mention all details explicitly. For this reason a fairly extensive bibliography has been included. It is by no means complete (in fact, over a 100 references are in the writer's possession), but should be consulted for a fuller description of the various topics mentioned. These journals may all be obtained through the Interlibrary Loan Scheme.

Design Requirements

Some of the more usual requirements are listed below, any one of which may be optimized at the expense of the other parameters.

(i) The gain in the direction of maximum radiation. For long arrays the power gain is proportional to length. Related to the gain is the width of the main lobe or beam. As the array becomes longer the beam widths in the E and H planes converge.

(ii) The position and amplitude of the sidelobes. Perhaps the main disadvantage of the Yagi-Uda designed from conventional methods is the high first sidelobe level, some 9db below the main lobe.

(iii) The front-to-back (F/B) ratio.

(iv) Operating bandwidth. This will usually be determined by the maximum allowable standing wave ratio, or distortion of the radiated pattern.

To obtain the best performance using any design method the elements' spacings, lengths and, to a lesser degree, the diameters can be varied. One may also vary the height above ground and length of the array. That one design can be called better than another of similar kind is a debatable point, depending very definitely on the parameter which has been optimized; comparisons are really only valid where the same parameter has been chosen for optimization.

Whether a long or short array is being designed experimentally, resort must be made to orderly variations in the physical dimensions. One parameter, e.g., director spacing, should be kept constant while another is varied, e.g., director length. Experiments have shown that a second co-planar linear reflector element gives very little improvement over the first.

One-way power gain is used on the various graphs with respect to a half-wave dipole, unless noted otherwise. Where possible, differences in experimental conditions are briefly mentioned on the graphs, which explain to some extent the variations in the results obtained. Experimental curves are denoted by symbols; plain curves are theoretical derivations.

Resonant Aerial Design

Two Elements. If a half-wave dipole is placed near another dipole, which is driven, then currents are induced in the first one whose phase and amplitude are a function of the spacing and length of the element, i.e., dependent on its reactance. Generally speaking, close spacing produces high currents involving high losses and wide spacing the reverse. So that the induced current, in conjunction with that of the driven element, produces a required radiation pattern, the element length will differ by quite a large factor from the free space value of $\lambda/2$. These above remarks are applicable to arrays of more than two elements also. The appropriate reduction factor for various diameter/wavelength ratios will be found in most Handbooks.

The driven dipole coupled to a parasitic radiator has been investigated at great length by a number of workers. Some of their findings have been summarized in Fig. 1.

Multiple Elements. The dividing line between short and long aerials may be taken as approximately one wavelength. As mentioned earlier an adequate design can be produced by considering each element as a lumped resonant circuit, i.e., by altering the lengths, diameters and spacings of each element one can vary the impedance of the element's equivalent circuit at the input terminals.

Greenblum [1] has considered aerials up to 8λ in length and gives many graphs obtained from experiments. Fishenden and Wiblin [2] discuss aerials over 1λ in length with equal director spacings and lengths for a given aerial. Nose [*QST*, March, 1958, 1960] also gives some useful results obtained at 2m with a short aerial, whereas Kmosko and Johnson [*QST*, January, 1956] have considered a longer aerial.

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As may be seen from Table 1, Fishenden and Wiblin covered quite a range of lengths in their experiments. Their results were obtained at frequencies of 600 Mc/s and 200 Mc/s. For their particular design they do not claim that maximum gain has been obtained. Besides using only a single reflector element, a mesh type and a trigonal type were also tried. The backward radiation can also be decreased, apparently, by adjusting the spacing and/or length of the last director, though this has not been noted elsewhere. The mesh reflector, if it subtends a suitable angle at the last director, can improve the F/B ratio but no figures are given and it would be a matter for experiment between two stations. The trigonal reflector consists of three elements spaced $\lambda/2$ in a plane at right angles and $\lambda/8$ behind the driven element. The improvement in power gain for long aerials was some 30 per cent compared to 10 per cent for a four directional aerial when this type of reflector was used.

Greenblum has dealt in detail with the Yagi-Uda's performance over a wide range—some 7-500 Mc/s. The results are summarized, in a number of useful graphs, certain of which are to be found in the ARRL *Antenna Book* (10th Edition). The three-element array is described with the aid of curves giving gain as a function of element spacing. At $0{\cdot}2\lambda$ spacing for both parasitic elements a gain of approximately 7db is obtained, with $l = 0{\cdot}45\lambda$. If the value of s_D, the director spacing, is such that $0{\cdot}15\lambda < s_D < 0{\cdot}25\lambda$ the change in gain is small. At spacings in excess of $\frac{3}{4}\lambda$ the pattern deteriorates to produce high sidelobes. Greenblum's results also indicate a change in director diameter, d, from $0{\cdot}002\lambda$ to $0{\cdot}01\lambda$ decreases length l by approximately $2\frac{1}{2}$ per cent.

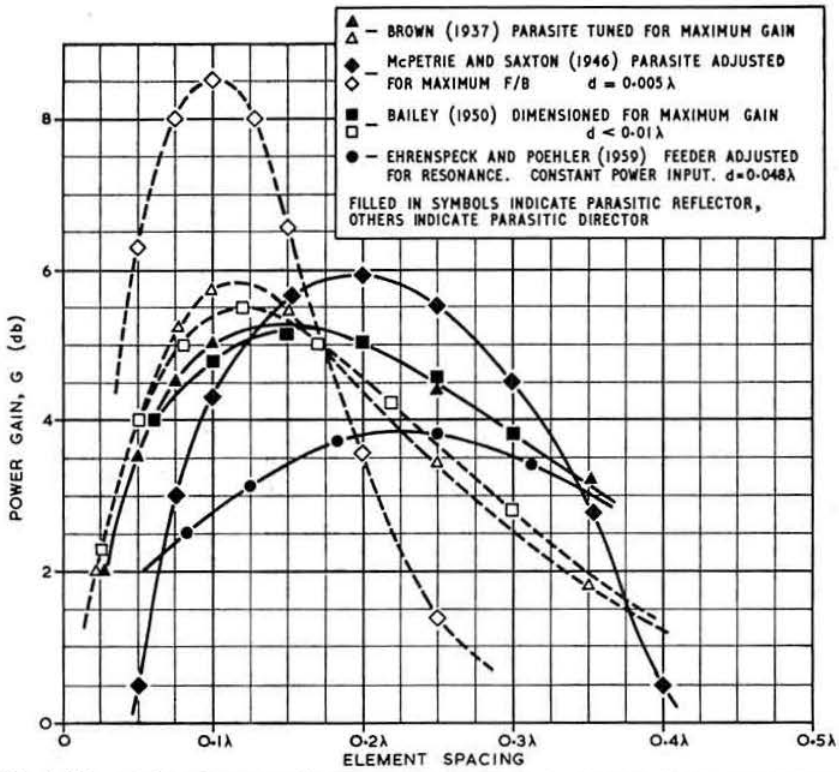

Fig. 1. The results of some authors showing the variation in gain for a two element array, using the parasitic element as a reflector or director.

TABLE 1

L	No. Elements	Power Gain db	Optimum Director Length (Sidelobe Amplitude 30 per cent)	Beamwidth at Half Field Strength Points degrees
1·36λ	4	9	—	46
1·70	5	—	0·434λ	—
2·38	7	—	0·423λ	—
3·06λ	9	11·1	—	37
3·40λ	10	—	0·42λ	—
4·42λ	13	11·8	0·414λ	31
6·80λ	20	13·2	0·407λ	26
10·2λ	30	—	0·40λ	22
14·38λ	42	—	0·385λ	—

These figures have been taken from Fishenden and Wiblin. The spacing used was 0·34 λ with emphasis on choosing the correct length for the number of directors used.

Surface-Wave Design

Uniform Array. The previous papers that have been briefly mentioned covered, in general, Yagi-Uda aerials up to a few wavelengths long. The method of design described in this section is of more modern vintage and may be applied to very long arrays. The dominant design principle is that a travelling surface wave can be propagated on various radiating structures, e.g., Yagi-Uda, helix, dielectric rods, etc., with a velocity under the control of the designer such that certain parameters can be optimized. As the aerial becomes longer, giving a higher gain, so the velocity approaches the free space velocity and at the same time the surface wave extends farther from the surface for a given amplitude. This implies that care must be taken in stacking the aerials, e.g., for a length $L \simeq 5\lambda$ the amplitude of the wave has decreased to 0·1 of its surface value at a distance of $\lambda/2$ from the surface. Up to 75 per cent of the input power can be radiated as a surface wave, the rest coming from the driven element as if the other elements were not present. For angles off end-fire direction that lie between approximately 45° and 315° the driven element is the main contributor to the pattern. That the surface wave may be established requires that L have a value,

$$L_{min} \not< \frac{\lambda}{6}\left(\frac{v}{c-v}\right)$$

In 1950, R. A. Smith suggested in his book† the controlling action of the director elements on the velocity, but no investigation was reported. At later dates other authors have

† *Aerials for Metre and Decimetre Wavelengths.*

used the surface wave concept to describe variations attained in the performance of the Yagi-Uda. Stated simply, the principle resulting from these investigations is, that if the allowable length, L, and the maximum gain, G, are known for the aerial then the propagation velocity, v, of the surface wave is uniquely determined, i.e., it has only one value. This value of v is also defined by an infinite number of combinations of the director parameters. The manner in which we choose the combination is irrelevant as long as v is obtained. In other words, two arrays may have the same gain and length but different numbers of directors if their lengths and diameters have been appropriately chosen.

Ehrenspeck and Poehler [3] have used this principle in their experimental investigations, which were restricted to using directors of *equal* height, spacing and diameter. The F/B ratio and sidelobe levels were also ignored, which may require for some cases the measurement of these quantities to see if a satisfactory design has been achieved. However, as the array is optimally designed (to their requirements) the theoretical value of −9·3db should possibly apply. This cannot be checked unfortunately as no patterns are presented in the article. The authors found that if the reflector/driven element combination was first adjusted for maximum forward gain (see Fig. 1) the addition of different numbers of directors had negligible effect on this adjustment.

With the addition of the directors it was found that the maximum gain was almost independent of their spacing up to approximately $s_D = 0{\cdot}4\lambda$ and with L varying up to 6λ and d up to $0{\cdot}048\lambda$. The authors were limited by practical reasons to these maximum values of L and d. The drop in gain that was apparent for $s_D = 0{\cdot}4\lambda$ could be counteracted to a great extent by an additional director spaced $0{\cdot}1\lambda$ from the feeder.

Some theoretical and experimental results are shown in Fig. 2 for the maximum gain obtainable over a range of L for the parasitic array as given by various authors. The wide spread in gain is probably due not only to differences between the aerials, but also to experimental error. The main conclusion seems to be that the curves indicated by circles and squares for the non-uniform arrays are together and above the curves for uniform arrays whose gains lie broadly in the region defined by

$$10 \log \left(\frac{3{\cdot}05L}{\lambda} \right) < G < 10 \log \left(\frac{5{\cdot}6L}{\lambda} \right)$$

The main results of Ehrenspeck and Poehler are shown in Fig. 3 from which one can design a Yagi-Uda by the simple expedient of drawing a line parallel to the x-axis from the required gain or array length to intersect with the appropriate curve. By doing this one is finding the optimum velocity to give maximum gain. Using this graph for designs below 1000 Mc/s, as an arbitrary figure, may not give optimum results as the element diameters used by the two authors are relatively large in the v.h.f. and u.h.f. regions.

For this type of aerial and others which have been designed for maximum forward gain Jasik‡ quotes an expression for the average half-power beamwidth,

$$\theta_{3db} \simeq 55 \sqrt{\frac{\lambda}{L}} \text{ degrees}$$

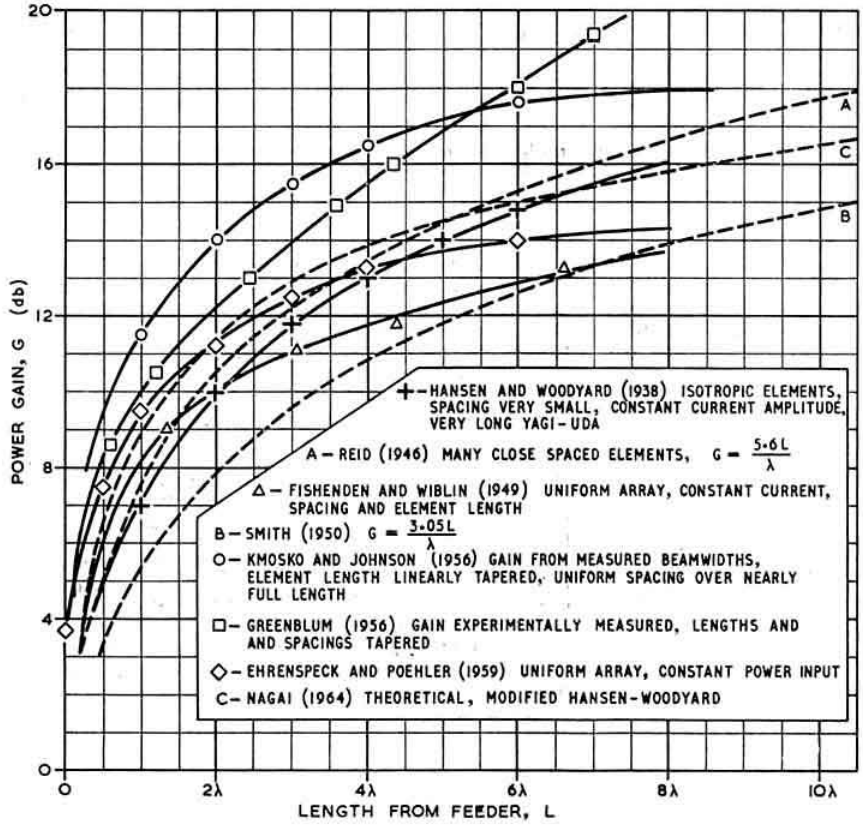
POWER GAIN, G (db)
LENGTH FROM FEEDER, L
PERCENTAGE TRANSMISSION
+ – HANSEN AND WOODYARD (1938) ISOTROPIC ELEMENTS, SPACING VERY SMALL, CONSTANT CURRENT AMPLITUDE, VERY LONG YAGI-UDA
A – REID (1946) MANY CLOSE SPACED ELEMENTS, G = 5·6L/λ
△ – FISHENDEN AND WIBLIN (1949) UNIFORM ARRAY, CONSTANT CURRENT, SPACING AND ELEMENT LENGTH
B – SMITH (1950) G = 3·05L/λ
○ – KMOSKO AND JOHNSON (1956) GAIN FROM MEASURED BEAMWIDTHS, ELEMENT LENGTH LINEARLY TAPERED, UNIFORM SPACING OVER NEARLY FULL LENGTH
□ – GREENBLUM (1956) GAIN EXPERIMENTALLY MEASURED, LENGTHS AND AND SPACINGS TAPERED
◇ – EHRENSPECK AND POEHLER (1959) UNIFORM ARRAY, CONSTANT POWER INPUT
C – NAGAI (1964) THEORETICAL, MODIFIED HANSEN-WOODYARD

Fig. 2. These curves describe the variation in gain of the Yagi-Uda with its length as found by various authors. Some are theoretical derivations, the others are experimental curves.

Non-uniform Array. In discussing the uniformity of arrays one can refer to the physical equality of the element spacing and length or to the current distribution in the elements. It has been assumed by some authors, for example, that the current amplitude in a Yagi-Uda is constant in each element, but this is not true for a parasitic array. Only if all the elements were driven would it be possible for such an amplitude distribution to be obtained. For a very long Yagi-Uda the distribution may be approximated by a constant, the greatest change occurring in the first three or four directors.

If the constant velocity of the previous section is changed in such a manner that its value along the array varies according to some law, then the array is said to be tapered. This is a further useful design principal as beneficial effects result from its application in regard to the sidelobe level, bandwidth, etc., but the tapering *must be gradual*. Reid suggests that tapered director spacing could give an improvement over the gain obtained from $G = 10 \log(5L/\lambda)$. Goward [4] and Sengupta [5] have discussed either or both

‡ *Antenna Engineering Handbook*, H. Jasik, McGraw-Hill.

tapering the length and spacing of the director elements.

When the parasitic elements are identical the only means available of changing the surface-wave velocity is by varying the interelement spacing, s_D. If the elements also have adjustable lengths then two methods are available. These are our only means of changing the elements' currents to improve the radiation pattern as compared to the case of the endfire array with separately driven elements. In this latter case the currents' amplitudes and phases are determined by the driving voltage and the impedance seen at the input terminals.

Another method [6] of improving the gain, in particular for the very long Yagi-Uda aerials, is to " modulate " the current amplitude. The Hansen-Woodyard criterion§ is applicable to such long aerials, as the current amplitude is virtually constant after a few wavelengths, but by giving the current a periodic variation in amplitude, say sinusoidal, such that an integral number of cycles are present over the whole length, the gain is increased. This gain increase can be as much as 2·2db (an effective transmitter power increase of roughly 1·7 times) over the Hansen-Woodyard value. However, if there are an integral number of half-cycles the gain is less.

It is also beneficial if the director lengths are tapered not necessarily over the complete length, but in the region next to the driven element, over roughly 20 per cent of L where v/c starts at 0·77–0·83. Also it will be found that tapering of just the last few directors of any of the designs is beneficial and should be done over the last half-wave length.

As already mentioned the fairly high sidelobes of the maximum gain design can be decreased by various tapering methods to the order of 20db below the maximum gain. A further 10db or so is possible by placing parallel rows of directors on either side of the array over the last half of its length at a spacing d given approximately by (see Jasik, p. 16-16),

$$\frac{d}{\lambda} \simeq \tfrac{1}{4}\sqrt{\frac{L}{\lambda}}$$

The sidelobe level of the uniform maximum gain design may be reduced to around −13db if some gain can be sacrificed, as Sengupta has shown with some experimental results. The aerial is operated at a frequency lower than the design frequency f_0 (approx. $0{\cdot}8f_0$ for −13db), the drop in gain being due to a broadening of the main beam. He then proposed *gradually* varying or tapering either or both all the directors' spacings and lengths as one goes along the array. If this is done the sidelobes can be reduced another 5db approximately without appreciably upsetting the forward gain. In doing this the surface-wave velocity varies inversely in some manner depending on the method chosen. The value of v is constant in Ehrenspeck and Poehler's design, for a given length. Sengupta has derived a useful equation for the velocity in terms of the spacing, length and radius of the elements and gives some criteria, quoted here, for the design of long Yagi-Udas.

(i) The directivity becomes less frequency sensitive for values of $s_D < \lambda/4$. Therefore as the optimum gain is not dependent on s_D for $s_D < 0{\cdot}4\lambda$ a reasonable choice is $0{\cdot}1\lambda < s_D < 0{\cdot}25\lambda$ with due regard to losses, cost of extra elements, greater wind loading and weight at close spacings.

(ii) The value of director diameter, d, is suggested to be $0{\cdot}05/k \leq d \leq 0{\cdot}15/k$ where k is the propagation constant of free space and is numerically given by $2\pi f/c$. For example, at 145 Mc/s with d = 1cm, a reasonable value, $kd = 0{\cdot}063$ which lies within the quoted range. This design, of course, is for a first sidelobe of no better than −9·3db. This is about 1½ S points; not a particularly effective value when the congestion on 2m is considered under good propagation conditions.

One of the main effects of tapering as suggested by Sengupta, is that the travelling surface wave is affected as little as possible by " jumping off " into space at the end of the array. If the phase velocity v approaches c, the speed of light, i.e. $v/c \longrightarrow 1{\cdot}0$ at the end, then this method of design should produce better results than the simpler designs of Spector [7], Ehrenspeck and Poehler and others.

An example of the tapered array

§ The criterion requires the phase shift along the array to be such that there is one extra half-wavelength present over the equivalent physical length of the array, in terms of the free space wavelength. *Proc. IRE*, 1938, p. 233.

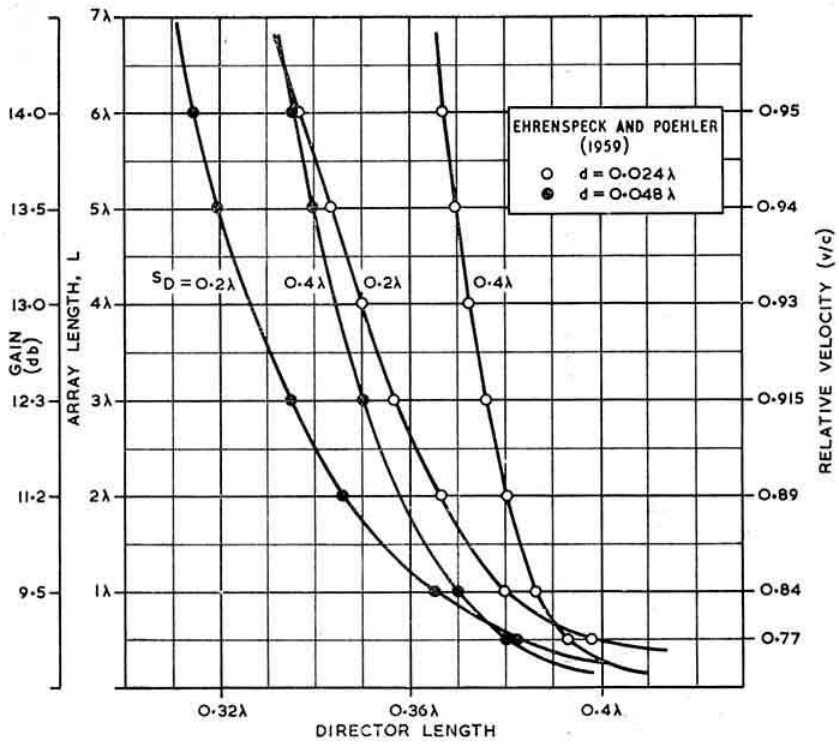

Fig. 3. This set of curves is given by Ehrenspeck and Poehler for the rapid design of a Yagi-Uda. It is thought inadvisable by the present writer to use them at frequencies in the v.h.f. region as the element diameters seem unsuitable. Note that the graph supplies all the information required for a particular design.

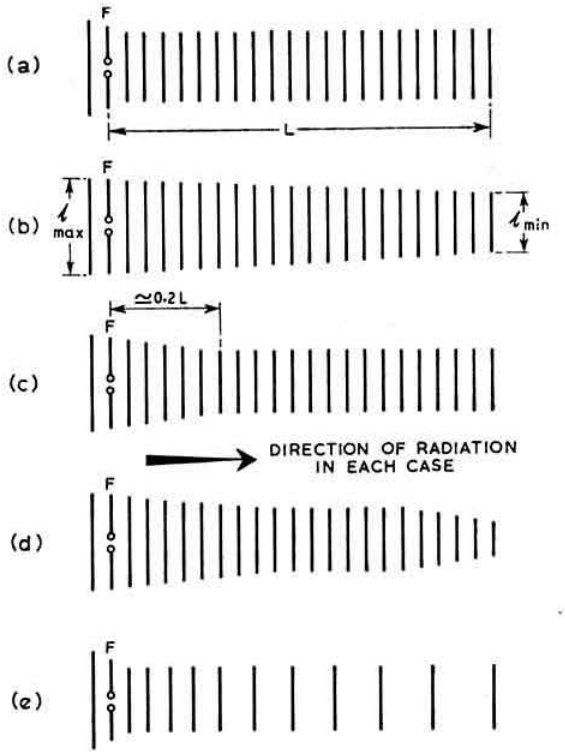

Fig. 4. Various schematic arrangements of the elements in long Yagi-Udas. (a) is the ordinary array such as used by Fishenden and Wiblin; (b) is the array described by Sengupta, and together with (c) and (d), shows forms of element length tapering. In particular (e) is an example of s_D being tapered. Sophisticated designs might take advantage of all these forms. For clarity the rates of tapering have all been exaggerated.

A typical value of l_{max}/l_{min} for $L = 6\lambda$ is 1·176.

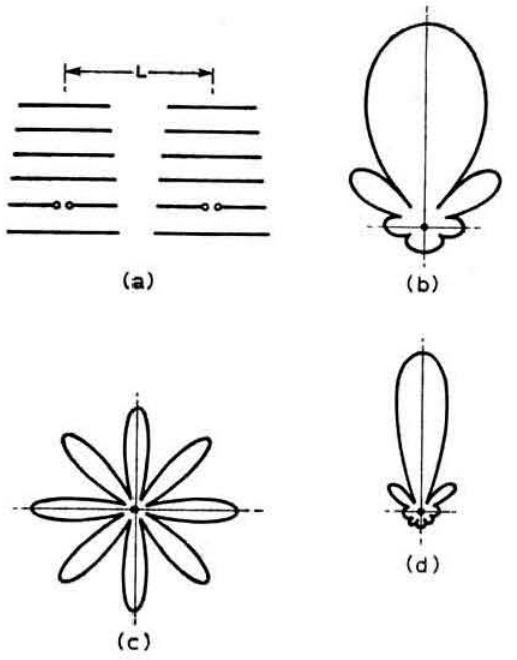

Fig. 5. A pair of spaced Yagi-Udas is shown at (a) each having separately the same arbitrary pattern shown in (b). The pattern of two isotropic aerials fed in phase and spaced 2λ is shown in (c). When pattern (c) is multiplied by (b) the resultant pattern of the two aerial array (d) is an improvement over (b).

empirally obtained is given in the previously quoted reference of Kmosko and Johnson, which is a combination of (c) and (e) in Fig. 4. A commercial array with tapering is the 10m " DX Long John " produced by Hy-Gain.

Miscellaneous Designs

Besides the standard planar, multiple, linear element array of Yagi and Uda, various authors have produced designs based on the original, having certain features in particular. These are briefly described.

A pair of crossed Yagi-Uda aerials at right angles on the same boom have been described by Messenger for polarization diversity reception (BULLETIN, December, 1962). It is necessary for a 90° phase shift to exist between the driving currents of the two driven elements, obtained with the appropriate lengths of coaxial cable, to give a performance better than a single aerial. Apart from the increased cost and weight it is suggested that this type of array should be seriously considered for its *superior performance* compared to the normal Yagi-Uda when constructing a beam, particularly at higher frequencies. Reynolds [8] has discussed the twisted Yagi-Uda where the elements all lie in different planes that intersect along the array axis. The use of two driven elements to improve the bandwidth has already been mentioned, and of course at microwave frequencies it is possible to launch the surface wave from a horn placed at one end.

A rather odd-looking design is mentioned by a number of authors. In this case the place of the linear elements is taken by metal discs placed on the boom [9, 10]. This can be done practically by soldering the discs to nuts and threading them on a screwed rod. The surface wave is propagated by appropriate choice of the spacing and diameter of the discs. At frequencies below say 1000 Mc/s this type would have a high wind loading and weight factor compared to the Yagi-Uda of similar size, but the discs could be made of expanded aluminium or copper wire mesh.

Yagi-Uda aerials have also been produced by cutting slots in curved and planar metal surfaces. This is a method usually restricted to missiles and high-speed aircraft. Circular elements or loops have been described by Doty [*QST*, November, 1958] in the form of a multi-element endfire array. This aerial was constructed for the 10m band using 72 ohm cable into a balun.

One fairly recent modification to the standard Yagi-Uda is the " backfire " aerial of Ehrenspeck and Poehler where the array is mounted so as to aim towards a plane reflector. The radiated wave passes back along the array setting up a standing wave. Circular and linear reflectors have been used with this aerial. The advantages accruing from this " backfire " Yagi-Uda are a higher gain, lower sidelobe and backlobe levels than the equivalent Yagi-Uda.

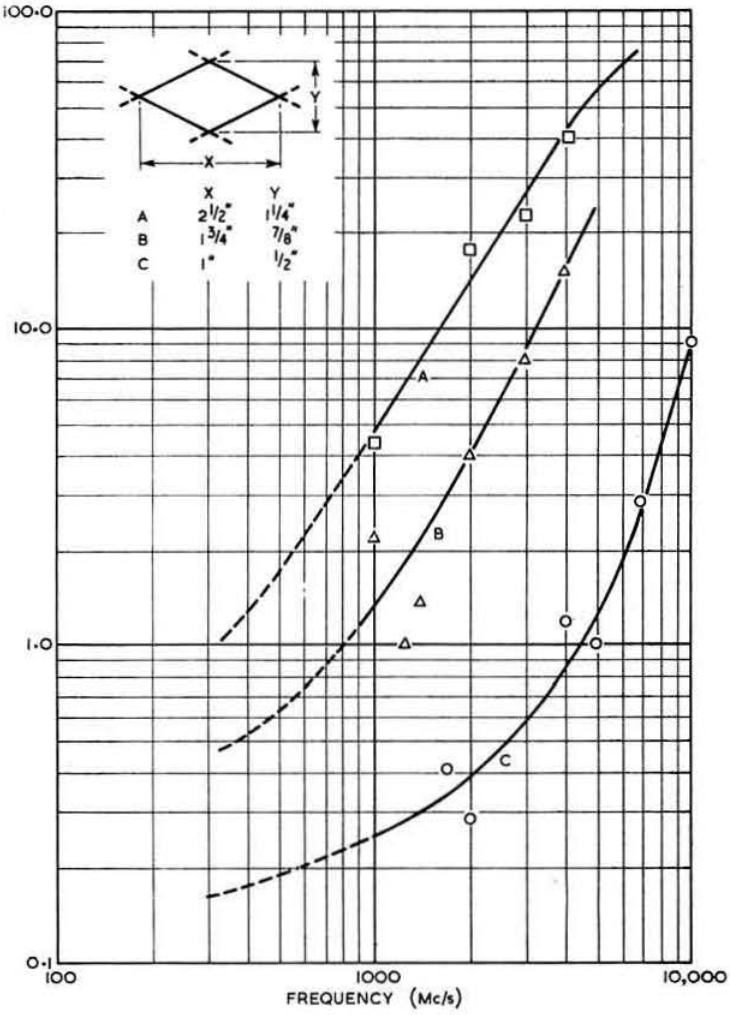

Fig. 6. These experimental points were obtained using the diamond mesh figure shown in the inset. The *E*-field polarization was parallel to the *X* dimension. The transmission was less than 0·1 per cent for a mesh ¾ in. × ¾ in. and is not therefore shown. Note that the scales are logarithmic and below 1000 Mc/s the curves are extrapolated.

Multiple Arrays

The main reason for using the beam aerials that have been described is to produce a maximum amount of radiated power in usually one preferred direction. To this end an improvement may be effected by stacking two or more and feeding them all in phase, so that one has a multiple array or an array of arrays. For example, if four Yagi-Uda arrays are placed vertically above one another then the field (or power) pattern will be narrow in the plane in which the arrays' axes lie, i.e., the vertical plane; alternatively if they are all placed side by side then the pattern is narrowest in the horizontal plane.

The resultant pattern of a multiple array can be obtained by using the theory of pattern multiplication. The field pattern of an array of *similar* aerials is the product of the pattern of the individual aerial (or element pattern) and the pattern of an array (or array factor) of isotropic aerials having the locations, amplitudes and phases of the non-isotropic aerials. For example, consider Fig. 5 using two Yagi-Uda aerials. If the pattern of a single Yagi-Uda is as shown and the pattern of two isotropic aerials replacing them is that shown, then the resultant pattern of the two Yagi-Udas is the product of the two patterns.

The pattern of the first example mentioned in this section may now be obtained in a similar manner. Only a brief sketch of the method has been given and the subject is covered in more detail in the handbooks, where the patterns of isotropic sources at various spacings are given.

More sophisticated methods utilize variations in the current amplitude and phase to each driven element in a multiple array to produce improvements in the overall pattern that Goward, Sengupta and others have obtained for single arrays. Two such examples are the Binomial and the Dolph-Tchebyscheff arrays.

Apart from making more efficient use of low power transmitters an array of aerials is a definite requirement for moonbounce experiments and is a help in areas surrounded by hills, in which case the " obstacle diffraction method " can produce surprising results [*QST*, March, 1958].

Reflectors

The use of some type of reflector is almost mandatory with the Yagi-Uda. Probably the most useful type at frequencies of 100 Mc/s and above is the expanded aluminium mesh obtainable from most radio supply shops, or even chicken netting which is cheaper and can at least be soldered easily. However, this latter type must be supported by a frame—a typical example is shown on page 407 of the RSGB *Amateur Radio Handbook* (Third Edition). Some results [11] have been published for mesh reflectors covering a range of 1 Gc/s–10 Gc/s and these are repeated in Fig. 6. The curves are extrapolated in the left hand region of the graph; the error will be less than an order of magnitude. A fairly well equipped amateur might be able to make some simple experimental measurements in this region using netting.

Feeding Arrangements

Methods of feeding the driven element of the Yagi-Uda are reasonably well covered in the handbooks. Further details on gamma matching will be found in the articles by Boss [*QST*, November, 1960] and those previously mentioned by Nose. By adding a reactive component across the input terminals of the driven element Gooch [*QST*, April, 1962] obtains what he calls the " hairpin " match. In cases where a folded element is used for the driven element a suitable balun is formed by passing the feed cable inside one half

(Continued on page 231)

C116 is most easily broken at terminal 9 of S21, the A.V.C./NL. switch and the wiring for S1b connected at this point. Convenient points for the connection of S1c are pin 6 of V6, and the main +150 volt line and C84 in the b.f.o. anode circuit.

Operation

The power switch of the AR88 is left in the REC. MOD. position, the functions of A.M./S.S.B. and C.W., A.V.C. TIME CONSTANT and B.F.O. ON/OFF all being performed by S1. In the A.M. position, a faint b.f.o. beat can be heard with the power switch turned to REC. C.W., due to direct radiation from the b.f.o. wiring. However, the level of the signal is far too low to affect the a.v.c. circuits and it was not considered worth attempting to improve the screening.

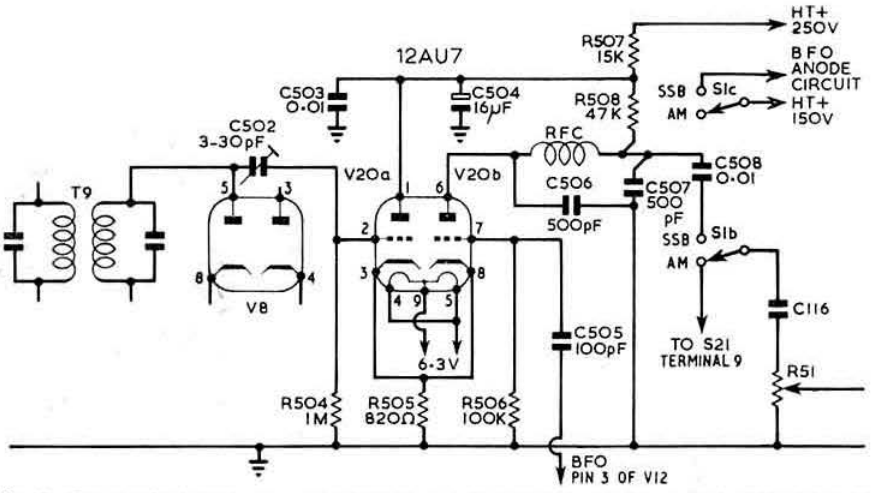

Fig. 3. The product detector and switching to retain the original a.m. detection facilities.

Panel Controlled Muting

The circuit shown in Fig. 4 enables the AR88 to be completely muted or used to monitor the signal from the transmitter, depending on the setting of a control on the front panel. The existing tone control is of little real value, in the author's opinion, and a simple modification enables it to perform a much more useful function. The lead from C117 is disconnected from the potentiometer R52, R55 is disconnected from ground and connected to the now free tag on R52. The lead to the DIVERSITY terminal on the rear terminal strip is removed and a wire from the junction of R52 and R55 taken there instead. This lead is, in turn, connected through a normally closed point on the transmit relay or switch to ground. In the transmit mode, this point is open and the monitoring level may be set by R52, the receiver being completely muted at just over half-travel of the control. Should the receiver subsequently be operated away from the transmitter, it is only necessary to turn R52 fully anticlockwise to remove its muting effect from the circuit.

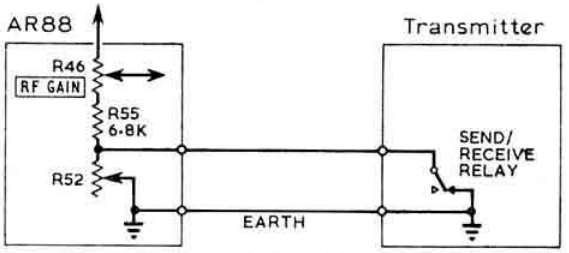

Fig. 4. A suitable muting circuit.

Conclusion

Of course, one could carry on and modify the AR88 almost beyond recognition, and there is no doubt that the receiver could be significantly improved, especially its selectivity shape factor. But, despite its vintage, this model is still adequate for most purposes, it is particularly rugged, and, perhaps of even more importance, new spares are still available.

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of the element to the input terminals of the dipole [*QST*, November, 1958].

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